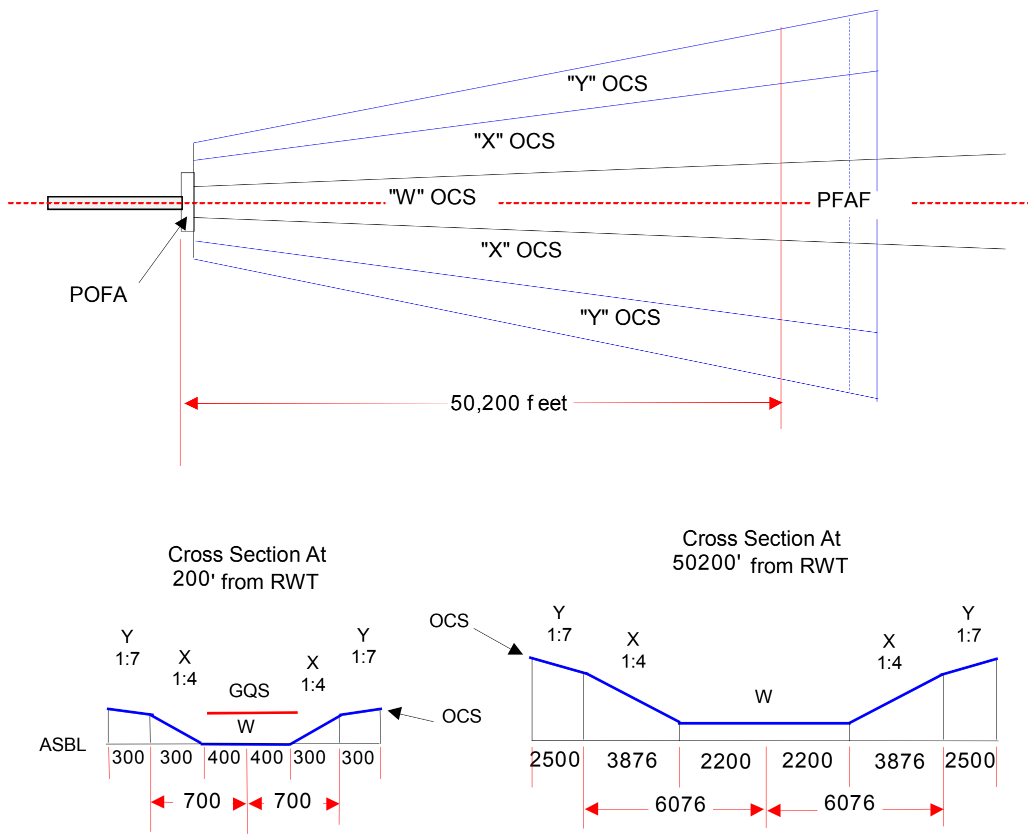
CHAPTER 3. LPV FINAL APPROACH SEGMENT (FAS) EVALUATION

3.0 FINAL SEGMENT.

The FAS originates 200 feet from LTP and ends at the PFAF (see figure 3-1). The primary area consists of the "W" and "X" obstacle clearance surface (OCS), and the secondary area is the "Y" OCS.

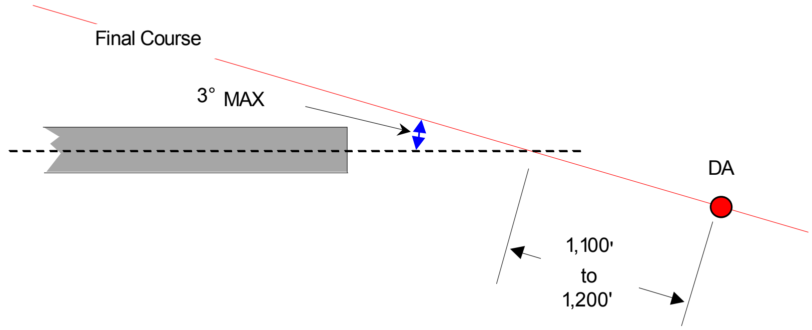
Figure 3-1. Obstacle Clearance Areas



3.1 ALIGNMENT.

The final course is normally aligned with the runway centerline extended (± 0.03°) through the LTP (± 5 feet). Where a unique operational requirement indicates a need for an offset course, it may be approved provided the offset does not exceed 3°. Where the course is not aligned with the RCL, the MINIMUM height above touchdown (HAT) is 300 feet, and MINIMUM runway visual range (RVR) is 4,000 feet/prevailing visibility ¾ SM. Additionally, the course must intersect the runway centerline at a point 1,100 to 1,200 feet toward the LTP from the DA point (see figure 3-2).

Figure 3-2. Offset Final



3.2 OCS SLOPE(S).

In this document, slopes are expressed as run over rise; e.g., 34:1. The OCS is comprised of three longitudinal sections of differing slopes. For a 3° glidepath angle, the three sections are: Zero slope (elevation equal to ASBL), 27.03:1 slope, and 34:1 slope (see figure 3-3). Determine the OCS slope associated with a specific GPA using the following formula:

Determine distance "D"

Formula 3.1

$$\mathbf{D} = 200$$

or if $\frac{\textbf{TCH}}{\tan(\theta)} < 954$

$$\mathbf{D} = 200 + \left(954 - \frac{\textbf{TCH}}{\tan(\theta)}\right)$$

Section 1 Slope: No Slope, level with ASBL

Section 2 Slope (S_2):

Formula 3.2

$$\mathbf{S}_2 = \frac{81.08}{\theta}$$

Where θ = GPA

Section 3 Slope (S_3):

Formula 3.3

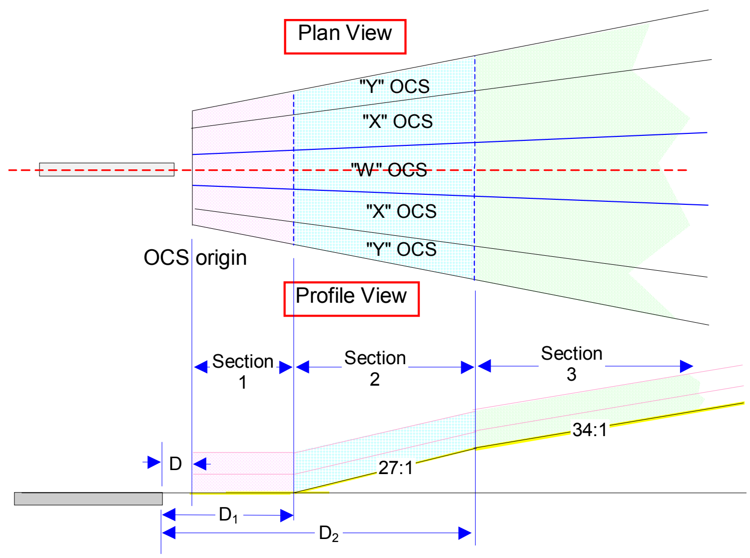
$$\mathbf{S}_3 = \frac{102}{\theta}$$

Where θ = GPA

3.2.1 OCS Origin.

The OCS begins 200 feet from LTP, measured along course centerline, and extended to the PFAF.

Figure 3-3. Distance from LTP to Beginning of Slope Rise



Formula 3.4

$$D_1 = D + 2{,}378.939$$

Formula 3.5

$$D_2 = D + 11{,}599.277$$

3.3 DETERMINING SURFACE WIDTHS.

In order to determine which surface (W, X, or Y) to use to evaluate an obstacle at a known perpendicular distance (d_y) from the final approach course, the width of the surfaces at the obstacle distance from RWT (d_x) must be determined. Calculate the perpendicular distance from the course centerline to the edge of the surface using the following formulae:

"W" Surface: Formula 3.6

$$0.036(d_x - 200) + 400$$

"X" Surface: Formula 3.7

$$0.10752(d_x - 200) + 700$$

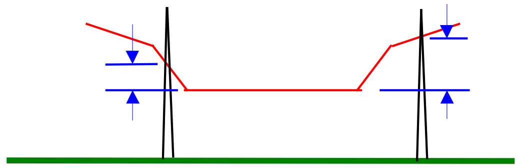
"Y" Surface: Formula 3.8

$$0.15152(d_x - 200) + 1000$$

3.4 OCS PENETRATIONS.

Evaluate obstacles at the longitudinal slope of the "W" surface. If obstacles penetrate the "X" or "Y" surfaces, calculate their "effective height" ($h_{effective}$) relative to the "W" surface and evaluate the obstacle as if it penetrated the "W" surface (see figure 3-4). To determine $h_{effective}$, use the following formula:

Figure 3-4. Calculating Obstacle Effective Height



Formula 3.9

$$h_{effective} = h - (x + y)$$

where h = height of obstacle
x = rise of "X" surface
y = rise of "Y" surface (may be zero)

Example: 1049' obstacle is located 4,600' from RWT.

Distance to edge of "W" Surface $=0.036(4{,}600\text{-}200)+400 = 558.40\,'$

Distance to edge of "X" Surface $=0.10752(4{,}600\text{-}200)+700 = 1{,}173.09\,'$

Distance to edge of "Y" Surface $=0.15152(4{,}600\text{-}200)+1000 = 1{,}666.69\,'$

CASE 1: Obstacle is in "X" surface, 1,000' from course centerline. It is $(1{,}000 - 558.40 = 441.6\,')$ from edge of "W" surface.

$$h_{effective} = 1{,}049 - \left(\frac{441.6}{4} + 0\right) = 938.60\,'$$

CASE 2: Obstacle is in "Y" surface, 1,250' from course centerline. It is $(1{,}250 - 1{,}173.09 = 76.91\,')$ from edge of "X" surface.

$$h_{effective} = 1{,}049 - \left(\frac{1{,}173.09 - 558.40}{4} + \frac{76.91}{7}\right) = 884.34\,'$$

3.4.1 LOWEST ELEVATION EVALUATED.

Determine the lowest obstruction MSL elevation (or effective elevation) to be considered in the OCS evaluation using the following formula:

{ The minimum HAT value attainable is 250 feet. The elevation derived from formula 3.10 represents the obstruction elevation that results in a 250-foot HAT value. Therefore, obstructions lower than this value need not be considered. The GQS and the visual segment evaluation surface evaluate these obstructions. }

Formula 3.10

$$LE = LTP_E + \frac{\dfrac{(250+(TDZE-LTP_E))-TCH}{\tan(\theta)} - D_1}{S_2}$$

Where LTP_E = LTP Elevation
TDZE = Touchdown Zone Elevation

LPV RATIONALE

Paragraph 2.8 - DETERMINING PFAF/FAF COORDINATE.

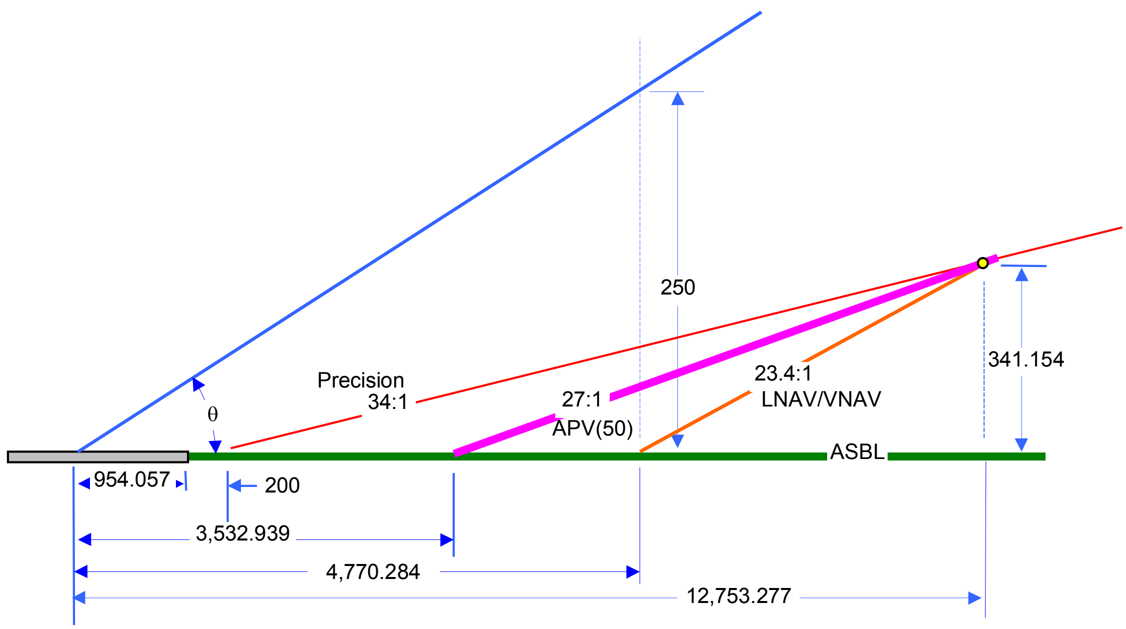
Step 1: Formula: $\boxed{\mathbf{Z} = \mathbf{A} - \mathbf{F}}$

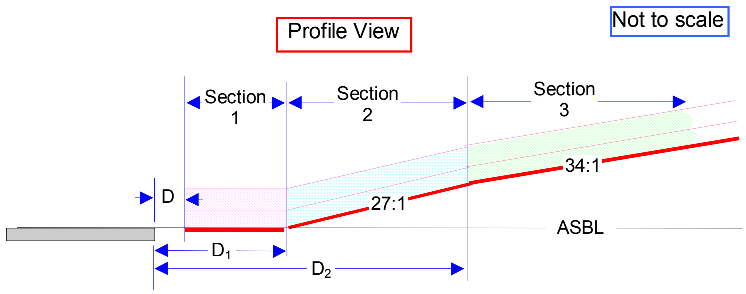
Step 2: Formula: $$\boxed{\mathbf{D} = 364{,}609\left[90 - \theta - \sin^{-1}\left(\frac{\sin(90+\theta)20{,}890{,}537}{\mathbf{z} + 20{,}890{,}537}\right)\right]}$$

Where: A = FAF Altitude in feet
F = LTP elevation in feet
θ = Glidepath angle

Rationale for formula. The formula is based upon a spherical model of the earth with a radius equal to the geometric mean of the semi-major and semi-minor axes of the WGS-84 ellipsoid (20,890,537 feet). The leading coefficient $(364{,}609)$ of the formula is the same radius multiplied by the degree-to-radian conversion factor $\left(\frac{\pi}{180} \times 20{,}890{,}537 = 364{,}609\right)$. Using this spherical model formula instead of a much more complex ellipsoidal solution which is both altitude and heading dependent results in errors less than one part in ten thousand over nominal glidepath lengths.

Paragraph 3.2 - OCS SLOPE(S).





Section 1:

ILS 5.33σ value for VAL is 12 meters

LPV with 5.33σ value for VAL is 50 meters

$\frac{50-12}{0.3048}=124.672'$ additional possible vertical bias error

$\frac{124.672}{tan(3°)}=2{,}378.883'$ Vertical bias error converted to longitudinal displacement

$\frac{50}{tan(3°)}+200=1{,}154.057'$ ILS GPI to OCS (34:1) origin minimum distance [50' TCH, 3°θ]

If GPI<954, then the 200-foot value must be increased by the amount GPI is short of 954

Let $\mathbf{D}=200$ if GPI ≥ 954

Let $\mathbf{D}=200+\left(954-\frac{\mathbf{TCH}}{tan(\theta)}\right)$ if GPI < 954'

$\frac{250}{tan(3°)}=4{,}770.284$ GPI to LNAV/VNAV OCS [23.4:1] origin

1,154.057+2,378.883=3,532.939 GPI to LPV OCS [34:1] where GPI ≥ 954'

$$\mathbf{D}_1=\mathbf{D}+3332.939-\frac{954\times tan(\theta)}{tan(\theta)}$$

$\boxed{\mathbf{D}_1=\mathbf{D}+2{,}378.939}$ RWT to LPV OCS origin

Section 2:

$$\frac{\left(\frac{250-50}{tan(3)}\times 34\right)-(200\times 23.4)}{34-23.4}+\frac{50}{tan(3)}=12{,}753.277$$ GPI to S_W/S_V crossover point

$$\mathbf{D}_2=\mathbf{D}+12553.277-\frac{954\times tan(\theta)}{tan(\theta)}$$

$\boxed{D_2 = D + 11{,}599.27}$ RWT to S_W/S_V crossover point

Slope is expressed as RUN/RISE in TERPS

RUN: 11,599.27-2,378.939=9,220.331

RISE: $\frac{11{,}599.27}{\frac{102}{\theta}}$

Slope (RUN/RISE): $\frac{9{,}220.331}{\frac{11{,}599.27}{\frac{102}{\theta}}}$ simplifies to: $\frac{\frac{102 \times 9{,}220.331}{\theta}}{11{,}599.27}$ simplifies to: $\frac{102 \times 9{,}220.331}{\theta \times 11{,}599.27}$ which simplifies to: $\frac{81.08}{\theta}$

$$\boxed{S_2 = \frac{81.08}{\theta}}$$

$\frac{81.08}{3} = 27.027$ Slope of LPV OCS from origin to SW/SV crossover point

Section 3:

$\boxed{\frac{102}{\theta}}$ Slope of Section 3

PARAGRAPH 3.3 DETERMINING SURFACE WIDTHS.

The widths of the final approach trapezoid are identical to the United States Standard for precision approaches stated in Order 8260.3B, United States Standard for Terminal Instrument Procedures (TERPS), Volume 3, Precision Approach (PA) and Barometric Vertical Navigation (Baro VNAV) Approach Procedure Construction.

PARAGRAPH 3.5 - SECTION 1.

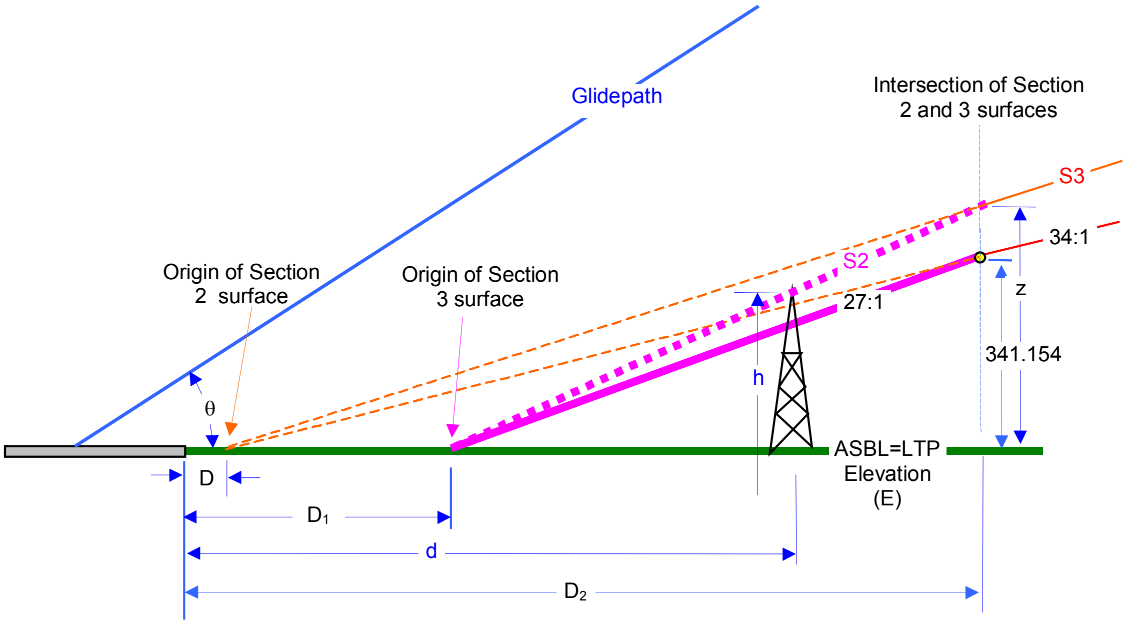
Section 1 is the application of the precision surface with a zero longitudinal slope. Penetrations of the "W", "X", or "Y" surfaces do not affect glidepath angle. Instead, the minimum DA is determined by adding the ROC value (vertical distance between the glidepath and ASBL at the obstacle) to the MSL height of the effective height of the obstacle.

$$\boxed{\begin{aligned} ROC &= \tan(\theta)\left(d + \frac{TCH}{\tan(\theta)}\right) \\ \text{Min DA} &= h_{MSL} + ROC \end{aligned}}$$

h_{MSL} = height above mean sea level

PARAGRAPH 3.6.1 - To determine the adjusted glidepath angle,...

Any adjustment in the slope of section 2 will affect the slope of section 3 because the sections share a common height at a point 12,753.277 feet from GPI.



$$S_2 = \frac{d - D_1}{h - E} \qquad z = \frac{D_2 - D_1}{S_2} \qquad S_3 = \frac{D_2 - D}{z} \qquad \theta = \frac{102}{S_3}$$

then by substitution:

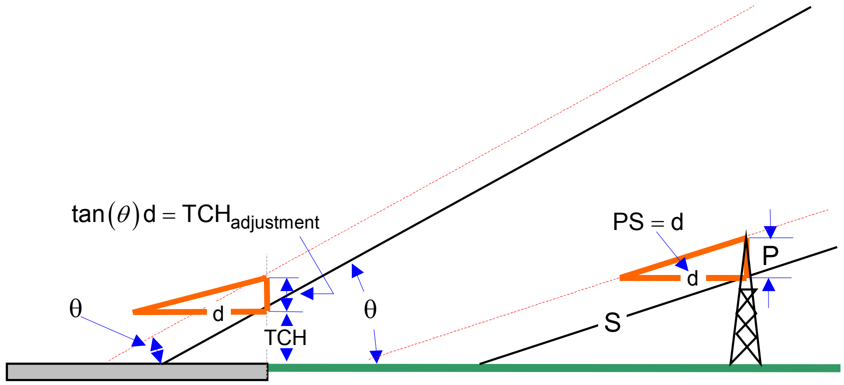
$$\frac{102}{\frac{D_2 - D}{D_2 - D_1 / \frac{d - D_1}{h - E}}} = \frac{102}{\frac{D_2 - D}{\frac{(D_2 - D_1)(h - E)}{d - D_1}}} = \frac{102}{\frac{(D_2 - D)(d - D_1)}{(D_2 - D_1)(h - E)}} = \frac{102(D_2 - D_1)(h - E)}{(D_2 - D)(d - D_1)}$$

Since D_2-D_1 is always 9,220.331:

$$\boxed{\theta = \frac{940{,}474.469(h - E)}{(D_2 - D)(d - D_1)}}$$

Paragraph 3.8 - ADJUSTING TCH.

Adjusting TCH in LPV criteria is the equivalent to relocating the glide slope antenna in ILS criteria. The goal is to move the origin of the OCS toward the runway sufficiently to cause the OCS at the obstacle location to raise to a point on top of the obstacle.



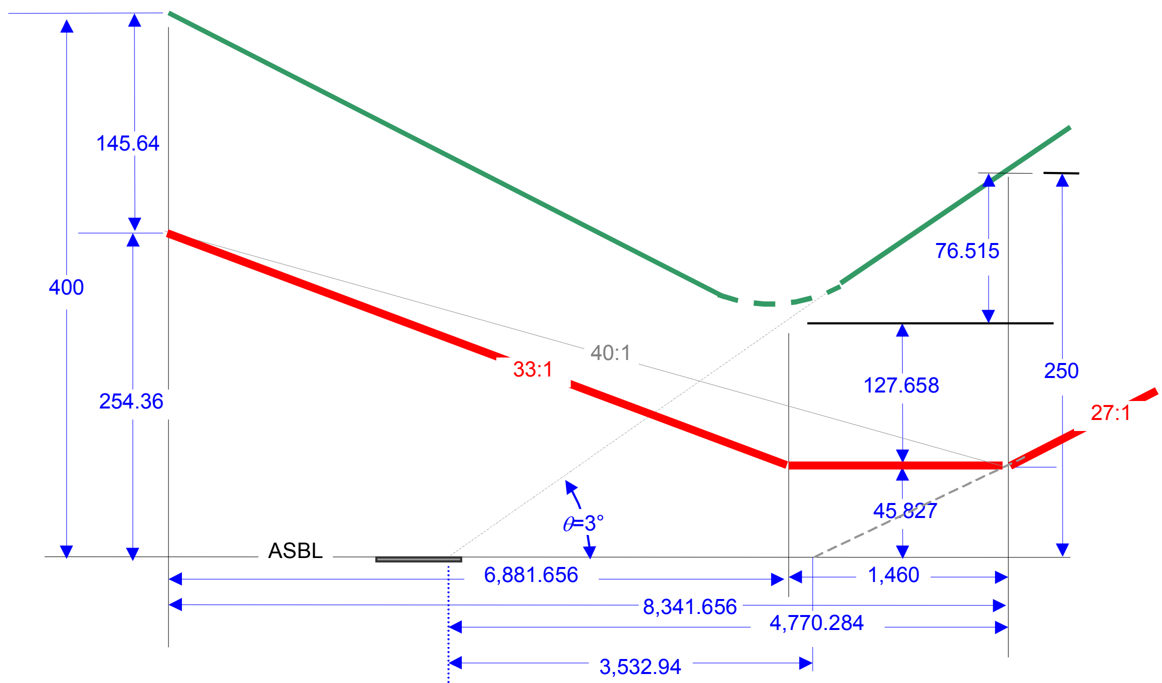
$$\boxed{TCH_{adjustment} = tan(\theta)PS}$$

where P = amount of penetration (ft)
S = slope ratio of penetrated surface
θ = glidepath angle

Example: $\tan(3)(4.5)(27) = 6.37$

Paragraph 4.1 - SECTION 1.

The dimensions of the missed approach segment are based on a standard glidepath angle of 3 degrees, TCH of 50 feet, 250-foot HAT, assumed height loss during 1,460 of horizontal flight descending on the glidepath, recovery of height loss and climb to 400 feet above ASBL. The following diagram depicts the derivation of stated values:



Height Loss: $1460 \times \tan(3) = 76.515$

Required Climb to 400: $400 - (250 - 76.515) = 226.515$

Distance required to regain 400: $\frac{226.515}{200} 6{,}076.11548 = 6{,}881.656$

Total length of section 1: $6{,}881.656 + 1{,}460 = 8{,}341.656$

Start of Section 2 from GPI: $\frac{(50-12)}{\tan(3) \times 0.3048} + \frac{50}{\tan(3)} + 200 = 3532.939$

Start of Section 3 from GPI: $\frac{\left(\frac{250-50}{\tan(3)} \times 34\right) - (200 \times 23.4)}{34 - 23.4} + \frac{50}{\tan(3)} = 12{,}753.277$

Elevation of OCS at DA re: ASBL: $\frac{4{,}770.284\text{-}3{,}532.94}{27} = 45.827$

Height re: ASBL of surface at end of section 1b if a 40:1 surface starts at DA: $45.827 + \left(\frac{8{,}341.656}{40}\right) = 254.368$

Slope ratio to reach 254.368 from end of section 1a: $\frac{6{,}881.656}{254.368 - 45.827} = 32.999 \approx 33$